



Climate Variability and Fisher Adaptation in Lakshadweep: A Qualitative Study of Coastal Observations

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Abstract

Coastal communities serve as vital observers of environmental change, and this study explores how small-scale fishers in the Lakshadweep Islands perceive and interpret climate variability through their lived experiences and traditional ecological knowledge. The research employed ethnographic and phenomenological approaches, conducting fieldwork across three inhabited islands: Kavaratti, Agatti, and Minicoy. Data was collected through semi-structured interviews, focus group discussions, participant observation, and participatory tools with 30 experienced fishers aged 25-70. Thematic analysis revealed three primary domains: perceived environmental changes, traditional indicators utilized by fishers, and adaptation strategies. Fishers consistently reported climate-induced alterations, particularly in monsoon patterns, sea conditions, and fish catch. Many continue to rely on traditional ecological knowledge to inform fishing decisions, but noted increasing unreliability of these indicators due to climate change. Adaptation strategies varied based on access to resources and experience, with younger fishers embracing technological tools and older fishers relying on accumulated knowledge. Community-based information sharing emerged as a significant resilience strategy. The findings underscore the importance of integrating local knowledge into climate adaptation policies and research. Recommendations include involving fishers in monitoring and planning, enhancing access to technology and training, strengthening livelihood support schemes, establishing community-based early warning systems, investing in participatory research, promoting climate education, and protecting coral ecosystems through local stewardship. The study highlights the value of indigenous knowledge in understanding and responding to climate variability, emphasizing the need for a hybrid approach that combines traditional wisdom with scientific innovation to build adaptive capacity in island communities like Lakshadweep.

Key words - Climate variability- Lakshadweep Islands- Traditional ecological knowledge-Adaptation strategies- Coral reef ecosystems

Introduction

Coastal systems and low-lying areas are particularly sensitive to sea-level rise and all associated impacts of climate change (IPCC 2014). Climate change and variability are increasingly acknowledged as significant threats to marine ecosystems and the coastal communities reliant upon them. Small island regions, such as the Lakshadweep archipelago in the Arabian Sea, are particularly susceptible due to their geographic isolation, limited adaptive infrastructure, and heavy reliance on fisheries for sustenance, economic livelihood, and cultural identity. The Lakshadweep archipelago, consisting of 36 coral islands, faces unique challenges in adapting to climate-induced changes in marine ecosystems. Rising sea temperatures and ocean acidification pose significant risks to the region's coral reefs, which serve as critical habitats for diverse marine species and support local fisheries. As a result, the island communities are grappling with the need to develop resilient fishing practices and alternative livelihoods to ensure their long-term sustainability in the face of environmental uncertainty. The impact of climate change on marine ecosystems and coastal communities, especially in small island regions like the Lakshadweep archipelago, presents considerable challenges. Small tropical islands are recognized for their high vulnerability to climate change and other natural hazards, with climate-induced risks such as ocean warming, acidification, changing storm patterns, and accelerated sea-level rise exacerbating existing vulnerabilities (Forbes et al., 2013). In terms of governance and adaptation, small island nations often face limited support due to their intrinsic governance challenges, resulting in fewer resources compared to larger counterparts (Glaser et al., 2018). For sustainable development, an integrated approach is needed, focusing on place-based understanding for adaptation strategies to address the unique coastal biophysical systems of individual islands (Forbes et al., 2013).

To effectively tackle the effects of climate change and ensure the long-term viability of small island ecosystems like those in Lakshadweep, a combination of environmental management, policy development, and local community involvement is essential. While scientific models offer general insights into climate patterns, the specific impacts are often more accurately understood through the daily experiences of communities that interact closely with their

environment. In the Lakshadweep Islands, traditional fishers have accumulated extensive ecological knowledge over generations by closely observing the sea, weather, and marine life. However, ongoing environmental changes, such as erratic monsoons, dwindling fish populations, coral bleaching, and rising sea levels, are beginning to disrupt this relationship, leading to uncertainty and affecting their ability to maintain their livelihoods. Despite being at the forefront of climate-related challenges, these communities' perspectives are frequently underrepresented in formal climate evaluations and policy-making processes.

The primary focus is to understand how fishers in Lakshadweep perceive and interpret the impacts of climate variability and how these perceptions shape their adaptive responses and decision-making in daily coastal livelihood activities. This study aims to examine the perceptions, interpretations, and responses of fishers in Lakshadweep to climate variability, informed by their daily interactions with the coastal environment. Employing a qualitative, community-based methodology, the research seeks to document local observations, traditional indicators of environmental change, and the adaptation strategies utilized by fishers. Understanding these perceptions not only addresses critical knowledge gaps in regional climate studies but also offers valuable insights for the development of culturally grounded and locally relevant adaptation interventions. Ultimately, the study highlights the importance of integrating indigenous and experiential knowledge into broader climate resilience planning for small island communities.

Lakshadweep: Climate Vulnerability and Ecological Significance

Lakshadweep, India's smallest Union Territory in terms of land area, is an archipelago located in the Arabian Sea between 8°N to 12°30'N latitude and 71°E to 74°E longitude. (Fig 1) It is the only coral atoll reef system in the Indian subcontinent and forms part of the northern segment of the Chagos–Maldives–Laccadive Ridge, a 2,500 km-long submerged mountain chain in the Indian Ocean. The Union Territory comprises 36 islands, including 12 atolls, three coral reefs, and six submerged sandbanks, with only 10 islands currently inhabited. Despite its modest land area of 32.20 sq. km, Lakshadweep has a lagoon area of 4,200 sq. km, territorial waters extending over 20,000 sq. km, and an Exclusive Economic Zone (EEZ) of approximately 400,000 sq. km, making it geopolitically and ecologically significant.

The islands are categorized into three main clusters:

- Aminidivi Group (e.g., Amini, Kadmat, Kiltan, Chetlat, Bitra)
- Laccadive Group (e.g., Androth, Kavaratti, Agatti, Kalpeni, Bangaram)
- Minicoy Group (Minicoy being the only inhabited island)

Lakshadweep's topography is characterized by low elevation, with island altitudes ranging from -0.4 to 6 meters above mean sea level, making it highly vulnerable to climate change impacts such as sea-level rise, storm surges, coastal erosion, and coral bleaching. The coastline stretches approximately 132 km, surrounding flat islands built primarily of coral debris and sand.

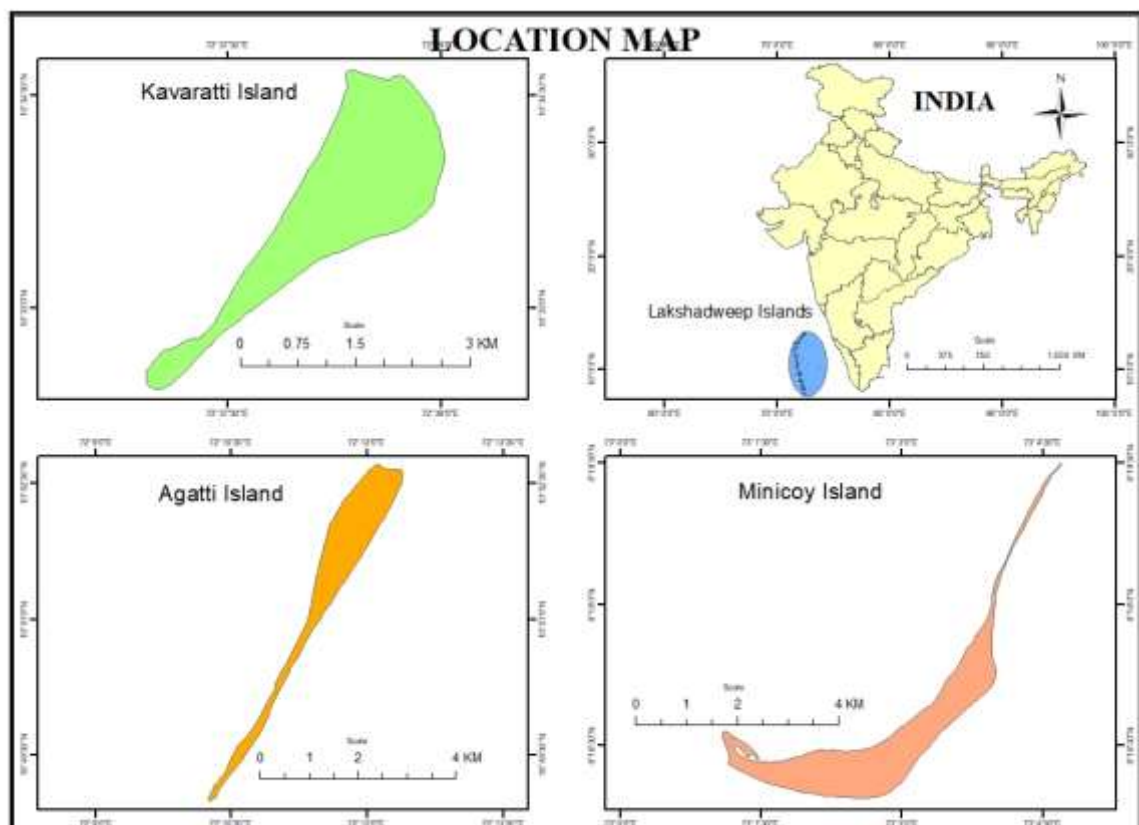


Fig 1 Location of the study area (Kavaratti, Agatti, and Minicoy islands)

Climatic and Ecological Vulnerability

The region is particularly sensitive to climate variability. It is witnessing frequent coral bleaching events, freshwater scarcity, and increasing threats to food security due to declining agricultural productivity and pressure on fish stocks. Rising sea levels and extreme weather patterns pose a direct threat to infrastructure, coastal settlements, and biodiversity. The loss of habitats critical for endangered marine species, such as sea turtles, rays, and sharks, along with changing disease vectors and marine ecosystem shifts, highlight the region's fragile ecological state.

Demographic and Socio-Economic Characteristics

According to the 2011 Census, Lakshadweep had a population of 64,429, including 33,106 males and 31,323 females, resulting in a population density of 2,013 persons per sq. km, among the highest in India. The entire native population is classified under Scheduled Tribes, reflecting their socio-economic vulnerability and geographic isolation. The territory is characterized by low economic inequality and a high literacy rate of 92.28%, second only to Kerala. The social structure remains largely egalitarian, with strong community ties and subsistence-based livelihoods. However, the increasing impact of climate change poses serious risks to the region's economic sustainability, health infrastructure, and ecological resilience.

Methods

The study employed a qualitative research design, combining ethnographic and phenomenological approaches to understand how fishers in the Lakshadweep Islands perceive and respond to climate variability. Fieldwork was conducted across Kavaratti, Agatti, and Minicoy—three inhabited islands selected for their ecological and cultural diversity. Participants included 30 experienced fishers aged 25–70, chosen through purposive and snowball sampling methods to ensure the inclusion of individuals with deep ecological knowledge and lived experiences of coastal changes. (Figure 2) Data collection involved semi-structured interviews, focus group discussions (FGDs), participant observation, and participatory tools such as photovoice and mapping exercises. These methods facilitated both individual and collective expressions of environmental change, particularly concerning shifts in weather patterns, fish migration, sea conditions, and coral health. All interviews and FGDs were audio-recorded, transcribed, and translated into English. Thematic analysis was conducted using Braun and Clarke's six-step framework(2006) with the aid of NVivo 12 software to identify recurring patterns and locally meaningful indicators of climate variability. Ethical approval was obtained from the relevant institutional review board, and informed consent was secured from all participants. Measures were taken to ensure anonymity, and findings were later shared with local communities through feedback workshops and educational materials in regional languages.



Figure 2 Methodology of Climate Variability and Fisher Adaptation in Lakshadweep

Results

The qualitative analysis yielded substantial insights into the perceptions and adaptive responses of Lakshadweep fishers to climate variability. Through thematic analysis of interview transcripts and focus group discussions (FGDs), three primary thematic domains were identified: Perceived Environmental Changes, Indicators Utilized by Fishers, and Adaptation Strategies.

Table 1: Perceived Environmental Changes Observed by Fishers

Environmental Change	No. of Respondents Mentioning (%)	Key Quotes
Shifts in monsoon timing	83% (25 out of 30)	"Rains come late now, and sometimes not at all."
Increased frequency of rough seas	76% (23 out of 30)	"Storms are unpredictable, even off-season."
Coral bleaching	60% (18 out of 30)	"Reefs have turned white; fish don't come there."
Decline in fish catch	90% (27 out of 30)	"Fish numbers have gone down year after year."
Shoreline erosion	53% (16 out of 30)	"The beach has shrunk; more sand is lost each year."

Table 1 shows Fishers from the three islands consistently reported climate-induced alterations, particularly in monsoon patterns and sea conditions. Notably, 90% of respondents indicated a substantial decline in fish catch, attributing this to both ocean warming and altered migration patterns. Additionally, coral bleaching and shoreline erosion were observed, with older fishers particularly noting these changes in comparison to past decades.

Table 2: Traditional and Local Indicators of Weather and Sea Changes

Local Indicator	Description and Use	Frequency in%
Wind direction	Used to predict rain and fishing conditions	70%
Sky colour at dawn/dusk	Used to anticipate storm formation	57%
Sea surface temperature (by touch)	Warm water linked to reduced catch	63%
Bird and dolphin behaviour	Used to locate fish or predict danger	50%
Cloud movement	Used for daily fishing planning	60%

Table 2 shows Many fishers continue to depend on traditional ecological knowledge, such as the interpretation of wind patterns, cloud movements, and animal behaviour, to inform their decisions regarding optimal fishing times and locations. These indicators are deeply rooted in cultural practices and demonstrate a profound understanding of the marine environment. However, several fishers have observed that these signs are becoming increasingly unreliable due to "changing weather rules," indicating a growing uncertainty associated with climate change.

Table 3: Adaptation and Coping Strategies Reported by Fishers

Strategy	Description	Reported by (%)
Changing fishing time/duration	Fishing during early morning or night to avoid rough seas	80%
Investing in GPS and depth sensors	Use of modern equipment to find fish and navigate	67%
Switching to lagoon or reef fishing	Avoiding deeper waters during high-risk months	56%
Participating in govt schemes	Using subsidies for nets, fuel, or insurance	40%
Community-based information sharing	Sharing storm news, fishing tips among peers	50%

Table 3 shows adaptation strategies among fishers exhibited variation contingent upon their access to resources and level of experience. While older fishers predominantly relied on intuition and accumulated experience, younger fishers demonstrated a greater propensity to embrace technological tools. Numerous fishers reported altering their fishing schedules or changing locations in response to increasingly turbulent seas. Furthermore, community-based cooperation emerged as a significant resilience strategy, particularly in remote islands where external support is limited.

Discussion

Lakshadweep's coastal communities exist in close harmony with their surrounding marine environment, where even minor climatic shifts can have profound implications for daily livelihoods and cultural traditions. In recent years, changing sea patterns, fluctuating fish stocks, and unpredictable weather have prompted new forms of local adaptation and resilience. This section explores how these communities interpret and respond to such environmental changes, highlighting the interplay between ecological knowledge, socio-economic realities, and adaptive behaviour.

Result of this study underscore the deep interconnection between Lakshadweep's coastal communities and their rapidly changing marine environment. The perceptions and lived experiences of local fishers reflect both acute awareness and concern regarding climate variability, particularly in relation to monsoon patterns, sea conditions, and fish availability. These local insights are critical in enhancing the understanding of climate change at micro-geographic scales, where

instrumental data is often limited. The study of Lakshadweep's coastal communities highlights the intertwined relationship between the inhabitants and their evolving marine environment. The archipelago, known for its fragile environment and marginal economy, faces unique challenges as it navigates the impacts of climate change. Local fishers in Lakshadweep, who are dependent on the sea for their livelihoods, have acute perceptions and experiences regarding climate variability, especially concerning monsoon patterns, sea conditions, and fish availability. These local insights are invaluable in understanding climate change impacts at micro-geographic scales, where instrumental data might be insufficient (Kokkranikal et al., 2003). Moreover, the recovery of marine ecosystems, such as coral reefs in Lakshadweep, following events like the El Niño-induced coral mortality of 1998, is strongly influenced by local conditions. The site-specific recovery patterns emphasize the need for localized conservation efforts that consider the unique hydrodynamics and ecological contexts of each atoll (Arthur et al., 2006). Overall, integrating local knowledge with scientific research is crucial for sustainable management and conservation strategies in Lakshadweep. This approach can ensure that efforts to mitigate the impacts of climate change are grounded in the realities of those who directly interact with these ecosystems on a daily basis. Similar observations of fishers' disconnection with the traditional skills and knowledge were noted by Nayak (2017) in the study in Chilika Lagoon, Odisha.

A striking majority of participants (90%) reported a consistent decline in fish catch over recent years, which they attribute to warming waters, coral bleaching, and shifting fish migration patterns. These observations align with scientific reports on climate impacts in tropical marine systems, where rising sea surface temperatures and acidification disrupt coral reef ecosystems and associated fish populations. Additionally, altered monsoon timing and increased storm unpredictability, reported by over 80% of fishers, resonate with regional meteorological data pointing to intensified climatic anomalies in the Indian Ocean basin. The decline in fish catch attributed to warming waters, coral bleaching, and shifting fish migration patterns is a multifaceted issue rooted in climate change impacts. Global climate change is influencing marine and estuarine fish populations by altering their distribution and abundance, driven by increased sea temperatures and changes in ocean currents. These shifts are affecting human communities dependent on fisheries for subsistence, commercial, and recreational purposes (Roessig et al., 2004). Coral reefs, which are particularly vulnerable to warming events, experience bleaching due to temperature-induced stress, resulting in significant habitat loss for many marine species. Coral bleaching leads to declines in fish populations that rely on these habitats, affecting fishers who depend on these stocks. In the Great Barrier Reef, and similar ecosystems, the degradation of coral due to warming causes poleward shifts in fish populations, with temperate species being replaced by more tolerant tropical species (Keller et al., 2009; Butler et al., 2007).

Projections suggest that ongoing warming will lead to more frequent and severe marine heatwaves, causing extensive damage to marine habitats and further reducing fish stocks. Consequently, fish catch potential declines, reducing fisheries revenues and endangering the livelihoods of people in coastal areas. This necessitates the development of adaptive management strategies to better cope with these changes, such as the formation of Marine Protected Areas (MPAs) and flexible fisheries management policies to protect remaining fish populations (Cheung et al., 2013; Macneil et al., 2010).

Importantly, the fishers' use of traditional knowledge—such as interpreting wind direction, cloud movement, and animal behaviour—serves as a valuable cultural asset in environmental monitoring. However, many respondents voiced growing uncertainty, indicating that these once-reliable signs are becoming less predictable. This suggests a perceived breakdown of ecological patterns long relied upon for survival, reinforcing the need for integrating local and scientific knowledge systems in adaptation planning. Traditional knowledge is an invaluable asset in environmental monitoring, especially as it involves centuries of accumulated wisdom from Indigenous communities about interpreting natural signs and behaviours to predict environmental changes. However, the integration of this knowledge into modern environmental assessment faces several challenges, which have led to a growing sense of uncertainty among Indigenous communities regarding the reliability of traditional indicators.

Firstly, there is often confusion over the definition of traditional knowledge and its ownership. This ambiguity hinders its effective use in environmental impact assessments (EIA) (Stevenson, 1996). Alexander et al. (2011) suggested traditional knowledge and indigenous narratives contribute to an adequate understanding of global warming. Integrating such indigenous narratives with the scientific knowledge exemplifies a valuable approach to assess climate change impacts and to recognize climate adaptation efforts. The integration of traditional ecological knowledge (TEK) and scientific ecological knowledge (SEK) is another area where challenges exist, particularly in educational settings. TEK offers a rich repository of environmental understanding that, when combined with SEK, can lead to more comprehensive environmental education and policy development. This integration, however, demands intellectual pluralism and a respectful evaluation of the epistemological differences between these knowledge systems (Kimmerer, 2012).

While traditional knowledge is an essential cultural asset for environmental monitoring, its integration into contemporary practices is challenged by definitional ambiguities, distrust due to past exploitations, and operational hurdles within environmental assessment processes. To enhance the reliability and application of traditional indicators, it is vital to foster respectful collaborations, adjust procedural frameworks, and acknowledge the cultural and epistemological foundations of Indigenous knowledge systems.

Adaptation strategies varied across age groups and access to resources. Younger fishers are increasingly incorporating modern tools such as GPS and sonar, whereas older generations rely more on embodied knowledge and experience. (Lauer & Aswani, 2009) (Musinguzi et al., 2015) (Foale, 2006) (Ban et al., 2017) This technological shift, while potentially beneficial, may also widen inequalities among fishers if access to devices and training is not equitable.

Moreover, community-based sharing of information about storms and fish availability emerged as a vital form of social capital that supports collective resilience. (Ramirez-Sanchez & Pinkerton, 2009) (Kesavan & Swaminathan, 2006) Government interventions, such as subsidies and insurance schemes, were mentioned but with mixed experiences. Some fishers reported difficulties in accessing formal support, indicating a gap between policy design and ground-level implementation. This points to the importance of tailoring climate adaptation policies to the specific socio-cultural and geographic contexts of small island communities. (Musinguzi et al., 2015) (Deb & Haque, 2017) (Jennings et al., 2016) In essence, this study reinforces the value of local ecological knowledge in understanding and responding to climate variability. While modern tools offer promise, empowering coastal communities through inclusive policies, participatory monitoring, and support for traditional practices remains essential. As climate change continues to affect marine livelihoods, a hybrid approach that integrates indigenous wisdom with scientific innovation will be key to building adaptive capacity in island ecosystems like Lakshadweep.

Conclusion

The exploration of fishers' experiences in the Lakshadweep Islands provides valuable insights into the intricate relationship between climate variability and coastal livelihoods. As environmental changes increasingly influence the rhythm of daily life and traditional fishing practices, understanding local perceptions and adaptive responses becomes essential. The concluding section synthesizes these insights, reflecting on how indigenous knowledge, adaptive behaviour, and policy gaps intersect to shape the resilience of Lakshadweep's fishing communities in a rapidly changing marine environment.

This research offers a nuanced understanding of how fishers in the Lakshadweep Islands perceive and respond to climate variability through their direct engagement with the marine environment. The findings reveal that local fishers possess a deep awareness of environmental changes, including altered monsoon patterns, declining fish catch, coral bleaching, and increased sea roughness—many of which align with broader scientific observations of climate change in the Indian Ocean region. Their traditional knowledge, grounded in generations of experience, continues to inform fishing practices and environmental interpretation, although many fishers noted that long-held ecological indicators are becoming less predictable due to the shifting climate.

Despite facing increasing uncertainty, Lakshadweep fishers have demonstrated significant adaptive capacity through behavioural changes such as shifting fishing times, utilizing GPS technology, and enhancing community-level information sharing. However, their efforts are constrained by limited access to resources, inconsistent government support, and lack of integration between traditional knowledge systems and formal adaptation policies. This underscores the urgent need to recognize and support the role of indigenous knowledge in climate resilience efforts. As climate variability continues to threaten the livelihoods and cultures of small island communities, placing fishers at the centre of research and policy frameworks is not only an ethical imperative but a practical strategy for sustainability.

Recommendation

Integrate Local Knowledge into Policy Planning: It is imperative for governmental bodies and non-governmental organizations to actively engage fishers in climate monitoring and adaptation planning, acknowledging their ecological knowledge as a valid and indispensable resource. **Enhance Access to Technology and Training:** Provision of affordable, region-specific tools (e.g., GPS, sonar, mobile-based weather updates) alongside training programs is essential to ensure that all fishers, particularly the older generation, can effectively utilize modern tools. **Strengthen Fisheries-based Livelihood Support Schemes:** Efforts should be made to improve the reach and transparency of schemes related to insurance, gear subsidies, and fuel support. Campaigns conducted in local languages can facilitate inclusivity. **Establish Community-Based Early Warning Systems:** Support should be extended towards the establishment of island-level networks for disseminating storm warnings and fish migration data, building upon existing community information exchange practices. **Invest in Participatory Research and Long-Term Monitoring:** The development of collaborative research programs that involve local fishers in tracking environmental changes, coral health, and fish stocks is crucial, integrating scientific methods with traditional observations. **Promote Climate Education and Youth Engagement:** Climate literacy and marine conservation should be incorporated into school curricula and community programs, ensuring that younger generations are equipped to navigate and address ongoing climate challenges. **Protect Coral Ecosystems through Local Stewardship:** Fisher-led marine stewardship programs should be encouraged to monitor and restore coral reefs, as their health is directly linked to fish availability and ecosystem stability.

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